

1 48899/DJB/A647

DIVE COMPUTER WITH GLOBAL POSITIONING SYSTEM RECEIVER

5 CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims priority of U.S. Provisional Application No. 60/394,982, filed July 8, 2002.

10 FIELD OF INVENTION

The present invention relates generally to underwater exploration and more specifically to apparatus and techniques for determining location during a dive.

15 BACKGROUND OF THE INVENTION

The development of self-contained breathing systems has enabled humans to dive and remain underwater for several hours. The ability to remain underwater for an extended period of time can enable divers to reach considerable depths and cover expansive distances in exploring underwater terrain.

20 A problem commonly encountered by divers is an inability to accurately locate position underwater. Position is typically expressed in terms of three co-ordinates. The position of a diver underwater can be expressed in terms of a latitude, a longitude and a depth co-ordinate. The latitude and the longitude co-ordinates represent the latitude and the longitude of a point on the surface of the water directly above the diver. The depth co-ordinate represents the depth of the diver below the surface of the water. A dive computer similar to a ProPlus 2 manufactured by Oceanic Worldwide of 25 San Leandro, California can be used to track depth during a dive. However, depth alone is insufficient to locate the position of a diver during a dive.

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SUMMARY OF THE INVENTION

5 Embodiments of the present invention can provide an improved method of locating position underwater by making measurements of latitude, longitude and time on the surface of the water and by measuring depth and time while under water. Several embodiments provide even greater accuracy in locating position underwater by also measuring water speed and bearing.

10 Embodiments of the present invention can also provide improved methods of interfacing with a dive computer involving the recording or recognition of speech or environmental sound and the ability to capture images of points of interest using digital cameras.

15 In one embodiment, the invention includes a processor, a global positioning system receiver connected to the processor and a pressure transducer connected to the processor.

20 A further embodiment of the invention includes means for measuring latitude, longitude, means for measuring depth underwater, means for measuring time and means for recording measurements of latitude, longitude, depth and time.

25 Another embodiment of the invention includes a processor, memory connected to the processor for storing data, a microphone connected to the processor and a pressure transducer connected to the processor.

30 A still further embodiment of the invention includes means for measuring depth, means for detecting sound and means for selecting one of a plurality of options in response to the detected sound.

35 Yet another embodiment of the invention includes means for measuring depth and means for capturing digital images.

One embodiment of the method of the invention includes performing a first measurement of latitude, longitude and time, descending underwater and measuring depth and time.

BRIEF DESCRIPTION OF THE DRAWINGS

5 FIG. 1 is a schematic illustration of an embodiment of a dive computer in accordance with practice of the present invention;

FIG. 2 is a flow chart illustrating a method of recording latitude, longitude, depth and time during a dive in accordance with practice of the present invention;

10 FIG. 3 is a flow chart illustrating a method of locating a point of interest using data recorded in accordance with practice of the present invention;

15 FIG. 4 is a schematic illustration of a dive computer including a buoy having a G.P.S. receiver antenna that is connected to the dive computer via a spool of communication cable;

FIG. 5 is a side view of a submerged diver equipped with a dive computer in accordance with the present invention including a buoy that is deployed at the surface;

20 FIG. 6 is a flow chart illustrating a method of recording latitude, longitude, depth and time during a dive in accordance with practice of the present invention that ensures that an automatic measurement of latitude, longitude and time is made as a dive is commenced;

25 FIG. 7 is a flow chart illustrating a method of recording locations that a diver considers important;

FIG. 8 is a flow chart illustrating a method of detecting speech commands in accordance with practice of the present invention;

30 FIG. 9 is a schematic illustration of an embodiment of a dive computer in accordance with practice of the present invention that includes an impeller and a compass;

35 FIG. 10A is a side view of a diver equipped with an air tank including a regulator and using a dive computer that includes an impeller and a compass mounted on the first stage

of the regulator in accordance with practice of the present invention;

5 FIG. 10B is a side view of diver using a dive computer that includes an impeller and a compass that is hose mounted;

FIG. 10C is a side view of diver using a dive computer that includes an impeller and a compass that is wrist mountable;

10 FIG. 11 is a flow chart illustrating a method of recording latitude, longitude, depth, time, bearing and water speed during a dive in accordance with practice of the present invention;

15 FIG. 11A is a flow chart illustrating a method of estimating the course taken by a diver based on G.P.S. measurements and water speed, depth and bearing measurements recorded during the dive;

20 FIG. 12 is a schematic illustration of an embodiment of a dive computer in accordance with practice of the present invention that includes a pressure transducer for measuring air pressure in an air tank; and

25 FIG. 13 is a flow chart illustrating a process for estimating the range of a diver using information concerning air time remaining and water speed.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, dive computers in accordance with practice of the present invention are illustrated. The dive computers make and record at least three significant sets of measurements, which enable the estimation of the location of points of interest underwater and the path travelled by a diver during a dive. The first set of measurements typically includes measurements of latitude, longitude and time immediately prior to the commencement of a dive. The second set of measurements can be

generated by periodically measuring depth and time during a dive. The third set of measurements can be compiled by measuring latitude, longitude and time immediately upon resurfacing from a dive. Following a dive, an estimation of location at a specified time during the dive using these three sets of measurements can be made by using a number of techniques in accordance with practice of the present invention. In several embodiments, the accuracy of the estimation can be increased by including measurements of speed and bearing in the second set of measurements.

Turning now to FIG. 1, a dive computer in accordance with practice of the present invention is illustrated. The dive computer 10 includes a processor 12 that is connected to memory 14, a G.P.S. receiver 16, clock circuitry 18 and an input/output interface 20. The input/output interface 20 is connected to a number of devices that can be used to communicate with a user or other devices. In one embodiment, these devices include a pressure transducer 22, a keypad 24, a display 26, a communications port 28 and a microphone 30. A digital camera 32 is also provided as an input device, however, the digital camera bypasses the microprocessor and is connected directly to the memory 14.

The processor 12 receives information from the G.P.S. receiver 16, the clock circuitry 18 and the input/output interface 20 and selectively stores the information in memory 14. In one embodiment, the processor is implemented using a MSP430F149 manufactured by Texas Instruments Incorporated of Dallas, Texas. However, the processor could be implemented using discrete logic components or several separate processing elements that share information.

The memory 14 can be used to store data logged by the dive computer 10, to temporarily store information during the performance of calculations and to store software used to

control the operation of the processor 12. The memory 14 need not be a single integrated circuit and can be constructed from a number of integrated circuits having distinct properties. In the illustrated embodiment, the memory 14 includes non-volatile memory circuits 34 to store software for controlling the processor 12, manufacturer settings, user settings and calibration data. In addition, the memory 14 also includes a removable memory device 36 that is used to store data logged during a dive such as images, a dive profile, dive logs, GPS logs and/or audio recordings. One aspect of using a removable memory device is that individual dives can be logged on separate removable memory devices and the removable memory devices used as a method of storing the logged data remote from the dive computer. In embodiments that use a MSP430F149 processor or equivalent processor device, the non-volatile memory included on the processor chip can be used to implement the non-volatile memory circuits 34 and the removable memory device can be implemented using a SDMB-128-768 128 MB MultiMedia Card manufactured by SanDisk of Sunnyvale, California. In other embodiments, memory devices of various sizes, volatility and portability can be used depending on the software requirements of the system and the data logging requirements of the user. For example, the removable memory device can be replaced by a similar sized fixed memory device such as a AT2508N-10SI-1.8 manufactured by Atmel Corporation of San Jose, California or an equivalent memory device.

30 The G.P.S. receiver 16 utilizes signals broadcast from satellites to make calculations of latitude and longitude. The G.P.S. receiver provides the latitude and longitude information to the processor, which is responsible for the processing and storage of the information. In one embodiment, the G.P.S. receiver is implemented using a GeoHelix-H GPS 35 antenna manufactured by Sarantel Ltd. of Wellingborough,

United Kingdom. In other embodiments, other G.P.S. receiver technologies, such as an Embedded 3.3V G.P.S. Antenna in
5 conjunction with an M-Loc™ MPM module both manufactured by Trimble Navigation Limited of Sunnyvale, California, can be used that are capable of providing information to the processor that can be used to generate latitude and longitude co-ordinates.

10 The clock circuitry 18 can be used to measure the passage of time. Typically the clock circuitry 18 will incorporate a quartz crystal that is used to generate a periodic signal that can be observed in order to measure the passage of time. The clock circuitry 18 can also be synchronized with an external
15 clock to enable time to be expressed in absolute terms using a time, a day, a month and a year. In one embodiment the clock circuitry is part of the MSP430F149 microcontroller described above. In other embodiments, the absolute time can be obtained using the G.P.S. receiver 16.

20 The input/output interface 20 can be constructed from any variety of wires, antennas, transmitters, receivers, connectors and buffers. The configuration of the input/output interface 20 is dependent on the input/output devices that are connected to the dive computer. In the embodiment shown in
25 FIG. 1, the input/output devices include a pressure transducer, a keypad, a display, a communications port and a microphone. In other embodiments, any other combination of input/output devices can be connected to the dive computer via the input/output interface. In one embodiment, the portion of the input/output interface connected to the pressure transducer includes a standard analog to digital converter. In addition, the input/output interface uses a display driver such as an S6B33A1 manufactured by Samsung of Seoul, South
30 Korea to connect to segment display 26 and a CS53L32A High

Speed Analog to Digital converter manufactured by Cirrus Logic, Inc. of Austin, Texas to connect to the microphone 30.

5 The pressure transducer 22 can be used to measure the pressure of the water in which the dive computer is immersed. In one embodiment a 17887.A Low Pressure Transducer manufactured by Pelagic Pressure Systems of San Leandro, California can be used to construct the pressure transducer 10 22. In other embodiments, other circuits capable of generating an electrical signal indicative of the water pressure in which the dive computer is immersed can be used.

15 A keypad 24 is typically provided to enable the user to enter information concerning the dive or to direct the processor 12 to provide the user with information. In one embodiment, the keypad 24 includes one or more buttons that can be used to tag the location of the user as a point of interest. As will be explained in greater detail below, the tagged location can be subsequently retrieved from the memory 20 14 of the dive computer 10. In other embodiments, the keypad 24 can include one or more buttons, toggles, joysticks or equivalent devices with which the user can provide instructions to the processor 12.

25 A display 26 is typically provided to present information in a graphical manner to the user. Information that can be provided to the user includes a recent G.P.S. reading, depth and/or time. If the dive computer 10 performs other functions, information relating to these functions can also be communicated using the display 26.

30 One skilled in the art will appreciate that the connection of keypads 24 and displays 26 to dive computers 10 is well known and any number of possible configurations, devices and circuitry could be used to establish a connection between these devices and the processor 12.

5 The communications port 28 is provided to enable the transfer of information between the dive computer 10 and other devices. In one embodiment, the communications port 28 is an Integrated Low Profile Transceiver Module IrDA standard such as the TFDU4100 manufactured by Vishay Semiconductor, Inc. of Malvern, Pennsylvania. In other embodiments, other wired or wireless connections and protocols can be used to communicate 10 with external devices. The transfer of information via the communications port 28 enables the movement of data and new software between the dive computer 10 and other devices. In one embodiment, dive information stored in the dive computer memory 14 can be loaded onto a personal computer and stored, graphed or manipulated. In addition, information from a previous dive stored on an external device can be loaded into 15 the memory 14 of the dive computer for reference during a subsequent dive or information stored within the dive computer can be manipulated by external devices.

20 The microphone 30 is provided to enable the audio annotation of data logged by the dive computer 10. The annotations can be made before, during or after a dive by making a digital recording of the words spoken by the user and associating them with a particular dive or with particular 25 tagged locations. In other embodiments, automatic speech recognition could be used to generate textual annotations. The addition of automatic speech recognition technology would also enable the dive computer to respond to audible instructions from the user. In one embodiment, the microphone 30 can be a 30 MAB-06A-B manufactured by Star Micronics Company, Ltd. of Edison, New Jersey. As described above, the input/output interface 20 can include an analog-to-digital converter for connection to the microphone. The analog-to-digital converter can sample the analog signal generated by the microphone 30 35 and generate a digital representation of the analog signal. In

one embodiment, the analog-to-digital converter samples the signal from the microphone 30 at a rate of 8 kHz and uses 28 5 quantization levels to represent the signal. In other embodiments, other sampling rates and a different number of quantization levels can be used as is appropriate.

In embodiments where automatic speech recognition is used, the processor 12 or a discrete device in the 10 input/output interface 20 can convert the digital representations of the signals from the microphone 30 to text or commands using hidden Markov models, neural networks, hybrid neural network/hidden Markov models or other speech modeling or recognition techniques. In one embodiment, speech 15 recognition is performed using a RSC-4x Speech Recognition Microcontroller manufactured by Sensory, Inc. of Santa Clara, California.

The digital camera 32 is provided to enable the capture 20 of images during a dive and to enable the use of these images as part of a dive log if desired by the user. The digital camera can be implemented using a lens and an array of charge coupled devices both of which are contained within the waterproof dive computer housing. In one embodiment, the digital camera is implemented using a MB86S02A CMOS sensor 25 manufactured by Fujitsu Microelectronics America, Inc. of Sunnyvale, California to capture image information and a MCF5307 Direct Memory Access Controller manufactured by Motorola, Inc. of Schaumburg, Illinois to transfer the image information directly to the memory 14. In other embodiments, 30 any circuitry capable of capturing a digital image can be used to obtain image information and store it in memory either via direct memory access or using the processor 12 in combination with the input/output interface 22.

Other input or output devices in addition to those 35 described above can be connected to a dive computer in

5 accordance with the present invention. In one embodiment speakers are connected to the input/output interface to enable the playback of recorded speech or to allow a diver to listen to music during a dive. In other embodiments, other combinations of devices can be used to meet the information requirements and data recording requirements of a diver during a dive.

10 Turning now to FIG. 2, a method 40 of recording information during a dive that enables estimation of position in accordance with practice of the present invention is illustrated. The method includes taking (42) a first G.P.S. measurement, which is performed prior to descending (44) below the surface. Once below the surface, depth and time are periodically measured (46). After ascending (48) to the surface, a second G.P.S. measurement is taken (50).

15 If data is logged during a dive in accordance with the method 40, then position during the dive can be estimated. If the user tags a particular location during a dive as being of interest, then the user can use the data logged in accordance with the method 40 shown in FIG. 2 to subsequently locate the point of interest.

20 Turning now to FIG. 3, a method of locating a previously identified point of interest using data logged in accordance with practice of the present invention is illustrated. The method 60 includes calculating (62) the duration of the recorded dive, calculating (64) the time that was taken to reach the identified point of interest from the start point of the dive and determining (66) a straight line 'L' between the start point of the dive and the end point of the dive. Once these functions have been performed, a value 'A' is then calculated (68), which is equal to the length of the line 'L' multiplied by the time taken to reach the point of interest and divided by the duration of the dive. The value 'A' is then

used to locate (70) a point 'P' , which is a distance 'A' from the start point of the dive along the line 'L'.

Once the point 'P' has been identified, a diver can travel (72) to the latitude and longitude of point 'P' and commence a dive. The diver can then enter the water and descend (74) to the recorded depth of the point of interest. At this depth, the point of interest can be located by searching (76) outwardly while attempting to maintain the recorded depth of the point of interest. The depth of a point of interest is particularly important in relocating that point. The co-ordinates calculated as the latitude and longitude of a point of interest using data collected by a dive computer in accordance with the practice of the present invention are simply estimates that place a diver in the vicinity of the point of interest. The knowledge of the depth at which the point of interest is located enables the diver to perform an expanding search in the plane of that depth. Without this information, a diver could be forced to search in three dimensions instead of two. The advantages of knowing a depth co-ordinate are increased when the point of interest forms part of the topography of the sea floor. A diver can rapidly locate such a point of interest by simply descending to the recorded depth of the point of interest and then searching outwardly from the point of descent until a portion of the sea bed is encountered at the recorded depth of the point of interest. By following the topography of the sea bed at the depth of the point of interest, the diver has a high likelihood of rapidly relocating the point of interest.

The method 60 illustrated in FIG. 3 can use data recorded in accordance with the method 40 shown in FIG. 2. The time recorded at the beginning of the dive and the time recorded at the end of the dive can be used to calculate (62) the duration of the dive. Likewise, the time at the beginning

of the dive and the time recorded at the point of interest can be used to calculate (64) the time taken to reach the point of interest. The latitude and longitude co-ordinates at the beginning of the dive and the latitude and longitude co-ordinates at the end of the dive can be used to generate the line 'L'(68) and the times calculated above can be used to locate the estimated latitude and longitude of the point of interest as described above.

Other techniques can be used to locate a point of interest using data recorded in accordance with practice of the present invention. In one embodiment, the logged data can be used to return to a point of interest by commencing the second dive at the latitude and longitude of whichever of the start and end points of the earlier dive was closest to the point of interest. The diver can then travel towards the other of the start and end points. The point of interest can then be located by traveling in this direction at the recorded depth of the point of interest for a time approximating the time it took to travel to the point of interest during the previous dive.

If a diver seeks to be able to return to a point of interest with a high degree of accuracy on subsequent dives, then the diver is advised to ascend to the surface at the point of interest. The dive computer 10 can then make a G.P.S. measurement and the diver can be confident that returning to the recorded latitude and longitude and descending to the recorded depth will enable rapid location of the point of interest.

An alternative to ascending to the surface is to use the dive computer 10' illustrated in FIG. 4 that includes a compass 70 and a G.P.S. antenna 72 mounted on a buoy 74, which is connected to the other components of the dive computer 75 via a spool 76 of communication cable 78. In other

embodiments, a wireless connection is used between the spool and the other components of the dive computer. When a diver 5 wishes to take a measurement of latitude and longitude at a point of interest, the buoy is released. At the surface, the antenna can receive the satellite signals required to measure latitude and longitude. These signals are then conveyed to the G.P.S. receiver via the communications cable. In other 10 embodiments, additional components such as the entire G.P.S. receiver can be included in the buoy. In one embodiment the spool is an AR-05 manufactured by Saekodive of Taiwan.

Displacement of the buoy relative to the position of the diver is illustrated in FIG. 5. The displacement of the buoy 15 74 relative to a position "P" directly above the diver can be calculated using Pythagorus' theorem by measuring the length of communication cable 78 released from the spool 76 and the depth of the diver. The length of communication cable released can be measured using markings on the cable 78 and 20 entered in the dive computer manually or via voice command. Alternatively an external line counter could be used that communicates to the processor of the dive computer via a wireless or wired link. The depth of the diver can be measured using the dive computer in the manner described 25 above. The direction of the displacement can be determined using a compass bearing of the cable relative to the diver.

Embodiments of the dive computer in accordance with practice of the present invention can enable automatic recording of latitude and longitude immediately prior to the 30 dive computer 10 descending below the surface of the water and immediately upon returning to the surface. Turning now to FIG. 6, a method in accordance with practice of the present invention for automatically recording the latitude, longitude and time prior to commencing a dive and upon surfacing from a 35 dive is illustrated. The method 90 includes making (92) and

5 storing (94) measurements of latitude, longitude and time using a G.P.S. receiver. The process of measuring latitude, longitude and time with the G.P.S. receiver and storing the values continues until the diver descends below the surface and the answer to the decision (96) of whether the diver has descended below the surface becomes affirmative.

10 Once the diver is below the surface, measurements (98) of depth and time are made and the measurements are recorded (100) in the memory of the dive computer. The measurement and recording of depth and time continues for as long as the diver remains below the surface and until the answer to the decision (102) of whether the diver has surfaced is affirmative. Once 15 the diver has surfaced, a measurement (104) of latitude, longitude and time is made and the measurement is recorded.

20 The method 90 described in FIG. 6 can ensure that the measurement stored at the commencement of the dive is the most recent measurement of latitude, longitude and time that has been made by the G.P.S. receiver 16 and dive computer 10. In addition, the method 90 enables periodic measurement of depth and time during the dive and the rapid recording of latitude, longitude and time when the diver resurfaces. In other 25 embodiments, the logging of latitude, longitude and time can be initiated in response to user input.

30 The method 90 shown in FIG. 6 can be modified to enable the diver to identify points of interest during the dive. Turning now to FIG. 7, a method in accordance with the practice of the present invention of identifying points of interest during a dive is illustrated. The method 110 is performed while the diver is under water. The method 110 can commence with the measurement (112) of depth and time. Once a measurement of depth and time has been made, the measurements are recorded (114). Prior to making another measurement of 35 depth and time, a check is made (116) for any user input. If

user input is detected, then the previous or next depth and time measurements are identified (118) as a point of interest.

5 In addition to identifying points of interest, it is desirable to be able to associate information with a point of interest. One advantageous method of providing inputs to a dive computer 10 is through the use of a microphone, as is described above. Speech commands can be used to control the 10 function of the dive computer and speech can be either recorded or converted to text in order to provide description or annotation to a point of interest. In embodiments where speech can be recorded, the recording of speech can be initiated by the pressing of a button on the keypad 24 or by a 15 voice command recognizable by the dive computer. In one embodiment, the microphone is contained within a full face mask enabling speech to be recorded underwater. In other embodiments, more than one microphone is included so that a diver may record speech using a first microphone and 20 underwater sounds or environmental noise using a second microphone. In embodiments of the dive computer 10 that include a digital camera 32, one or more still images or a series of still images forming a video sequence can be recorded and associated with a point of interest.

25 Turning now to FIG. 8, a method in accordance with practice of the present invention is illustrated for responding to voice commands. The method 130 includes listening (132) for sound. Once sound is detected, a decision 30 (134) is performed to determine if a "voice spotting" sound has been detected. A "voice spotting" sound is a spoken word such as "computer" that can indicate that a user is preparing to speak a command to a dive computer 10.

35 If the "voice spotting" sound is detected, then the method involves listening (136) for a command. A dive computer 10 in accordance with practice of the present invention will

5 typically have a library of commands each requiring different responses from the processor 12. If a sound is heard, then a decision (138) is performed to determine whether the sound corresponds to one of the commands recognized by the dive computer 10. If a command is recognized, then a response is made (140) to the command. Once the response is complete, the process 130 returns to listening (132) for sound to await the
10 next command.

15 The method 130 described above uses a "voice spotting" technique. In other embodiments, "voice spotting" is not required. The speech recognition performed in "voice spotting" and detecting commands can be either discrete or continuous
20 recognition. The speech recognition can also be either speaker dependent or speaker independent. In embodiments where annotation of points of interest can be performed, a speech command can cause the processor to begin digitally recording speech and to associate the recording with a particular point of interest. In other embodiments, other forms of user input
25 can be used to identify a point of interest and to commence the digital recording of speech. Alternatively, a command can cause the processor to convert a passage of speech to text using speech recognition techniques and to associate the text with a point of interest that can be identified using speech commands or using an alternative user input technique.

30 As was observed above, latitude, longitude and time measurements made in accordance with practice of the present invention can be used to estimate the latitude and longitude of a point of interest. The accuracy of this estimate can be effected by currents and the variation in the speed at which the diver traveled during the dive. The accuracy of the estimated latitude and longitude of a point of interest can be improved in accordance with the practice of the present
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invention by taking measurements of water speed and bearing as is discussed below.

5 A dive computer 10" in accordance with the practice of the present invention including an impeller and a compass is illustrated in FIG. 9. The dive computer 10" is similar to the dive computer 10 illustrated in FIG. 1, but with the addition that an impeller 150 and a compass 152 are connected 10 to the processor via the input/output interface. Impellers are devices that generate signals that can be used to measure the flow rate of a liquid or the water speed of the dive computer. By attaching an impeller equipped dive computer to a diver, the output of the impeller can be used to measure the 15 speed at which the diver is moving through water and the compass can be used to provide signals to the processor indicative of the direction in which the diver is moving. In one embodiment, a 3000 impeller manufactured by Nielsen-Kellerman of Chester, Pennsylvania, in conjunction with a 20 receiver coil connected to a counter that can be used to implement the impeller and a HMC 1055 3-axis magnetic sensor manufactured by Honeywell International of Morristown, New Jersey, that can be used to implement the compass. In other 25 embodiments other types of flow measurement devices can be used to measure water speed.

A diver equipped with a dive computer in accordance with the present invention is illustrated in FIG. 10A. The dive computer 160 is implemented as two discrete components 162 and 164. The first component 162 is worn around the wrist of the 30 diver and includes all of the components of the dive computer 10" illustrated in FIG. 10A except for the impeller and the compass. The impeller and the compass are located in a second component 164 that is fixed to an air tank worn 166 by the diver. In the illustrated embodiment, the two components 35 communicate via a wireless communications link.

Typically, a diver is fully extended while swimming and fixing the impeller in a direction parallel to the long axis 168 of the diver as the diver swims provides an accurate measurement of the speed of the diver. In addition, mounting the compass so that the bearing measurement is made along a line parallel to the long axis of the diver also enables an accurate measurement of bearing to be made. In order to ensure that both the impeller and compass are accurately aligned, it is desirable that the impeller and the compass be fixed to maintain a position relative to the body of the diver throughout the dive. Therefore, in the embodiment illustrated in FIG. 10A the impeller and the compass are fixed to the air tank 166 and aligned to be approximately parallel to the long axis 168 of the body of the diver, when the diver is fully extended. In other embodiments, the impeller and the compass can be fixed to other locations on the body or equipment of a diver. In other embodiments, the compass and impeller are included in a single unit with the other components of the dive computer and the position of the impeller and the compass can be controlled by the diver. A diver can use such a dive computer in accordance with the present invention to take instantaneous current readings, to use instantaneous speed calculations to calculate range based on air time remaining (see discussion below) or for any other application where an instantaneous measurement of speed can be useful. An example of a hose mounted dive computer 10" including an impeller and a compass is illustrated in FIG. 10B and an example of wrist mountable dive computer 10" including an impeller and a compass is illustrated in FIG. 10C.

A method of recording data in accordance with practice of the present invention is shown in FIG. 11. The method 40' is similar to the method 40 illustrated in FIG. 2, with the difference that the periodic measurements of depth and time

are supplemented with periodic measurements of bearing and water speed.

5 Assuming there is insignificant current, the measurements obtained using the process illustrated in FIG. 11 provides a complete map of the course taken by a diver. The starting latitude and longitude locations provide the origin of the course and the path followed by the diver can be determined
10 using the water speed, bearing, depth and time information. Factors such as drift current can be accounted for by scaling the course to ensure that it terminates at the location where the diver surfaced, as measured using the G.P.S. receiver. This scaling can be performed by the dive computer or by an
15 external device that manipulates data provided by the dive computer.

In one embodiment, the process illustrated in FIG. 11A is used to adjust or scale the course obtained using recorded water speed and bearing measurements in response to the latitude and longitude measurements obtained at the origin and termination of a dive. The process 170 includes defining
20 (172) a planar co-ordinate system at the origin of the dive using the co-ordinates x, y and z, where z represents the depth dimension. Calculating (174) position co-ordinates relative to the origin of the path taken during the dive using
25 the water speed, depth and bearing data. Determining (176) position co-ordinates of the termination point of the dive based on the water speed, depth and bearing data. Determining
30 (178) position co-ordinates of the termination point of the dive based on the G.P.S. receiver measurements of latitude and longitude. Calculating (180) the scaling factors that the x and y co-ordinates of the termination point determined using the water speed, depth and bearing data must be multiplied by in order to obtain the x and y co-ordinates of the termination
35 point determined using the G.P.S. receiver measurements of

5 latitude and longitude. An estimate of the path taken during the dive is then obtained (182) by scaling the x and y co-ordinates of the points in the path determined using the recorded water speed, depth and bearing measurements by the calculated scaling factors. The estimated path can then be output (184) in terms of latitude, longitude and depth by mapping the co-ordinates of the path from the planar co-ordinate system that was defined relative to the origin of the 10 dive to latitude, longitude and depth co-ordinates.

15 An embodiment of a dive computer in accordance with the present invention that incorporates pressure transducers in order to measure air time remaining is illustrated in FIG. 12. The dive computer 10" includes a pressure transducer 200 that measures air pressure inside an air tank. In one embodiment, the pressure transducer 200 is implemented using a high pressure sensor such as a 18519.A manufactured by Pelagic Pressure Systems of San Leandro, California. Air pressure 20 measurements can be converted into air time remaining statistics in accordance with the methods described in U.S. Patent 4,586,136 to Lewis and U.S. Patent 6,543,444 to Lewis, both of which are incorporated herein by reference in its entirety.

25 Knowledge of the water speed of the diver and the change in air time remaining can be used to generate useful information for a diver such as an estimation of the range that a diver can travel with the air remaining in the tanks of the diver. A process for calculating an estimation of range 30 based on the air available to a diver is illustrated in FIG. 13. The process 220 includes recording speed over a predetermined period of time (222) and then calculating the average speed during that period of time (224). Once the average speed has been calculated, the air time remaining is 35 calculated (226). The air time remaining calculation can be

used in combination with the average speed calculation to predict the range of the diver at current exertion levels. In 5 other embodiments, the air time remaining can be adjusted to reserve sufficient air to allow the diver to return to the surface from the depth at which the diver is located without significant risk of decompression sickness.

Although the foregoing embodiments are disclosed as 10 typical, it will be understood that additional variations, substitutions and modifications can be made to the system, as disclosed, without departing from the scope of the invention. Thus the present invention has been described by way of 15 illustration and not limitation. For example, embodiments of the invention can have G.P.S. receivers adapted to be submerged in water that are not connected to the processor. These embodiments log latitude, longitude and time information using the G.P.S. receiver and separately log depth and time 20 information using a dive computer. The latitude, longitude and time information from the G.P.S. receiver and the depth 25 and time information from the dive computer can be downloaded to the dive computer or another computer and the methods described above can be used to determine position. In addition, dive computers in accordance with the present invention can perform functions performed by conventional dive computers such as providing divers with information concerning 30 decompression limits or the amount of air remaining in a tank, however, it is not a limitation of the invention that the dive computer perform these functions or other functions typically associated with conventional dive computers. Other functions 35 can also be performed by the dive computer that are not traditionally associated with dive computers such as functions normally attributed to personal digital assistants (P.D.A.s) or other more powerful computing devices. In addition, dive computers in accordance with the present invention may consist

of a conventional dive computer and a microphone and/or a
5 digital camera and do not require the inclusion of a G.P.S.
receiver. Other embodiments of dive computers in accordance
with the present invention may also combine several of the
features described above such as a buoy including a G.P.S.
antenna, a compass and an impeller.

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